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A PROXIMATE DISTRIBUTION OF ΔB

For a description of the distortions of the geomagnetic field in the magnetosphere, ΔB provides a useful measure. Figure 1 shows approximate equi-ΔB contours for the two 90^o sectors centered at the noon and midnight meridian half-planes, based on a preliminary sampling of a much greater body of OGO 3 and 5 Rubidium magnetometer data

For this preliminary presentation the data for the southern hemisphere were combined with those for the northern hemisphere assuming symmetry with respect to the geomagnetic equator in spite of the fact that the tail neutral sheet does not necessarily coincide with the geomagnetic equator. The data used in Figure 1 were taken during periods when Kp was 0 or 1.

The negative ΔB values in the equatorial region between L = 2 and 6 represent the field depression from the quiet time ring current. The maximum field decrease is approximately 35γ. The $\Delta B > 0$ regions at higher latitudes on the nightside reflect the combined effects of the magnetic field inflation due to the equatorial ring current, the neutral sheet current in the tail, and the boundary surface current. There is an indication that a region of slightly low ΔB exists at about 20 to 30^o latitude and between 6 and 8 R_e, but it is not certain whether this is real or from a seasonal effect that is not taken into account in averaging. It is noted, however, that there is a similar tendency in the ΔB contour map for Kp = 2 or 3 to be shown in Figure 2.

On the front side, the $\Delta B = 0$ line drawn at low latitudes with the present data matches very well the corresponding line at higher latitudes determined by Heppner et al. (1967) from the OGO 1 results. The change of the sign for ΔB across this line is mainly from the boundary surface current.

An equi-ΔB contour map based on the data taken during slightly disturbed periods with Kp = 2 or 3 is presented in Figure 2. This ΔB map differs from that shown in Figure 1 for magnetically quiet periods in several respects: (i) the ring current is intensified; (ii) the tail field is increased; (iii) ΔB in the high ΔB region (above $\sim 30^{o}$ latitude) becomes larger; and (iv) the $\Delta B = 0$ line on the front side changes its shape.

Parallelism between Dst (mainly representing the ring current field) and ap (a measure for polar substorm activity) has been noted earlier (Sugiura, 1964), but a comparison of Figures 1 and 2 clearly demonstrates that even during relatively weak substorms the quiet time ring current is intensified. Increases in the tail field during high Kp periods have been discussed by Behannon and Ness (1966) and Ness and Williams (1966). Calculations based on the boundary surface current model of Mead (1964) and the tail current model of Williams and Mead (1965) show that the high ΔB values exceeding 40γ or even 50γ observed by OGO 1, 3, and 5 above $\sim 30^{o}$ latitude cannot be explained by these models, confirming the earlier conclusion reached by Heppner et al. (1967) from the OGO 1 observations. Still unanswered is the question of whether the magnetic field inflation caused by the ring current is enough to account for such high ΔB values, and if not enough, whether there is an additional pressure exerted from the polar region of the magnetosphere. In a later, more comprehensive analysis the possibility that the ΔB distribution depends on not only instantaneous but also previous magnetic activity will be examined.

SPATIAL DISCONTINUITIES IN THE NEAR TAIL REGION

The high β region in the nightside magnetosphere is referred to here as the "near tail" region. The dynamics of this region appears to be a key to the understanding of magnetospheric disturbance phenomena. In this section, magnetic field structures in the near tail region under relatively quiet conditions are discussed.

Figure 3 shows the variation in B on an inbound pass of OGO 3 near midnight. The steady tail field is abruptly interrupted by a sudden decrease in B at 11.3 R_e and at 12.7° geomagnetic latitude. Such a sudden decrease in B followed by irregular field variations is a feature repeatedly observed by OGO 3 on its nightside low latitude passes. When the satellite crosses the geomagnetic equator near 10 R_e the sudden drop in B is dramatic as seen in the example shown in Figure 4. In contrast to the sharpness of the variation in its magnitude the direction of the magnetic field does not generally indicate any abrupt change.

By estimating the kinetic energy density of the plasma based on the electron flux measurement by Frank (1967, 1968a, 1968b) it is found that the plasma kinetic energy density abruptly increases at the time a sharp decrease is observed in B. Plasma measurements in the tail by the Vela group indicate that the proton kinetic energy density is greater than (and probably several times) the electron kinetic energy density (Bame et al., 1967). If this is so then it can be concluded that the abrupt decrease in B corresponds to a traversal of a discontinuity between a $\beta << 1$ region and a $\beta \gtrsim 1$ region. Sometimes two or more step type discontinuities are observed on one pass. Thus the near tail region appears to have shell like structures with a discontinuity between successive shells filled with plasmas of different kinetic energy densities.

TAIL FIELD CHANGES DURING SUBSTORMS

The OGO 1 and 3 magnetic field measurements in the tail indicated that in association with polar substorms on the earth, magnetic field disturbances are observed in the tail only near the meridian plane of the negative bay onset on the earth, that the tail field changes are delayed relative to the bay onset time on the ground by several to fifteen minutes, and that the tail field changes are such as to approach the dipolar configuration (Heppner et al., 1967; Sugiura et al., 1968). Thus at the onset of a negative bay the plasma pressure is abruptly released in the near tail region in the vicinity of the magnetic midnight meridian because of a highly channeled, rapid convection of the plasma (Heppner, 1969) or a drainage of the plasma triggered by the bay onset, and the tail magnetic field collapses beyond this region. This collapsing process proceeds tailward in a relatively narrow region along the magnetic midnight meridian. The electron behavior in the tail plasma sheet observed by Vela 2 during magnetic bays (Hones et al., 1967) seems to support this picture.

HIGH β REGION ON THE DAWN FLANK OF THE MAGNETOSPHERE

The OGO 1 magnetic field measurements have shown (i) that at low geomagnetic latitudes near the dawn meridian the average gradient in B is essentially zero between $\sim 11\ R_e$ and the magnetopause; (ii) that frequently there is very little contrast between magnetospheric and magnetosheath fields near the magnetopause, making boundary identification difficult using the magnetic field data alone; and (iii) B in the magnetosheath is sometimes greater than B immediately inside the magnetopause

(Heppner et al., 1967). Based on these observations it was concluded that β must be approximately equal to, or greater than, unity in the low field-gradient region near the dawn meridian.

The more recent OGO 5 observations have confirmed the OGO 1 results, and have provided examples in which this equatorial high β region extends to near local time 9 hours. In addition, whereas the previous argument for the presence of high β plasma in the region concerned was solely based on the magnetic field observations, the OGO 5 electric field measurements show that the total plasma flux in this equatorial region is often comparable to, if not greater than, the plasma flux in the adjacent magnetosheath.

SUMMARY

The following aspects of the distortion of the geomagnetic field in the magnetosphere are discussed on the basis of the magnetic observations by the OGO 1, 3, and 5 satellites:

(1) Approximate distributions of ΔB (the magnitude of the measured field minus the magnitude of the reference field) are given in the noon and midnight sectors of the magnetosphere for magnetically quiet (Kp = 0 or 1) and slightly disturbed (Kp = 2 or 3) conditions. The field depression in the region of $L \lesssim 6$ caused by the quiet time ring current is shown to increase even during weak disturbances. The existence of regions of large ΔB above about 30° geomagnetic latitude cannot be accounted for by the existing theoretical models for the magnetopause surface current and the neutral sheet current of the tail, and is unlikely to be explainable by

the inflation due to the ring current. Large ΔB values in these regions may be a result of an additional pressure exerted from the polar regions of the magnetosphere.

(2) A sudden decrease in the magnetic field followed by irregular variations was often observed near midnight on low latitude inbound orbits of OGO 3. Comparing with the plasma observations this sudden decrease is interpreted as a traversal of the boundary between a low β region of the tail and an equatorial region of $\beta \gtrsim 1$ (i.e., the plasma sheet).

(3) Following the onset of a negative bay disturbance on the ground the magnetic field in the tail collapses near the meridional plane of the bay onset. Thus the bay-associated tail field change is such as to make the field configuration more dipolar.

(4) On the dawn side of the magnetosphere the magnetic field gradient is near zero in the equatorial region between about 11 R_e and the magnetopause. In this region the magnetic field in the magnetosheath is often comparable to, or even greater than, the field immediately inside the boundary. These observations suggest presence of a high β plasma in this region.

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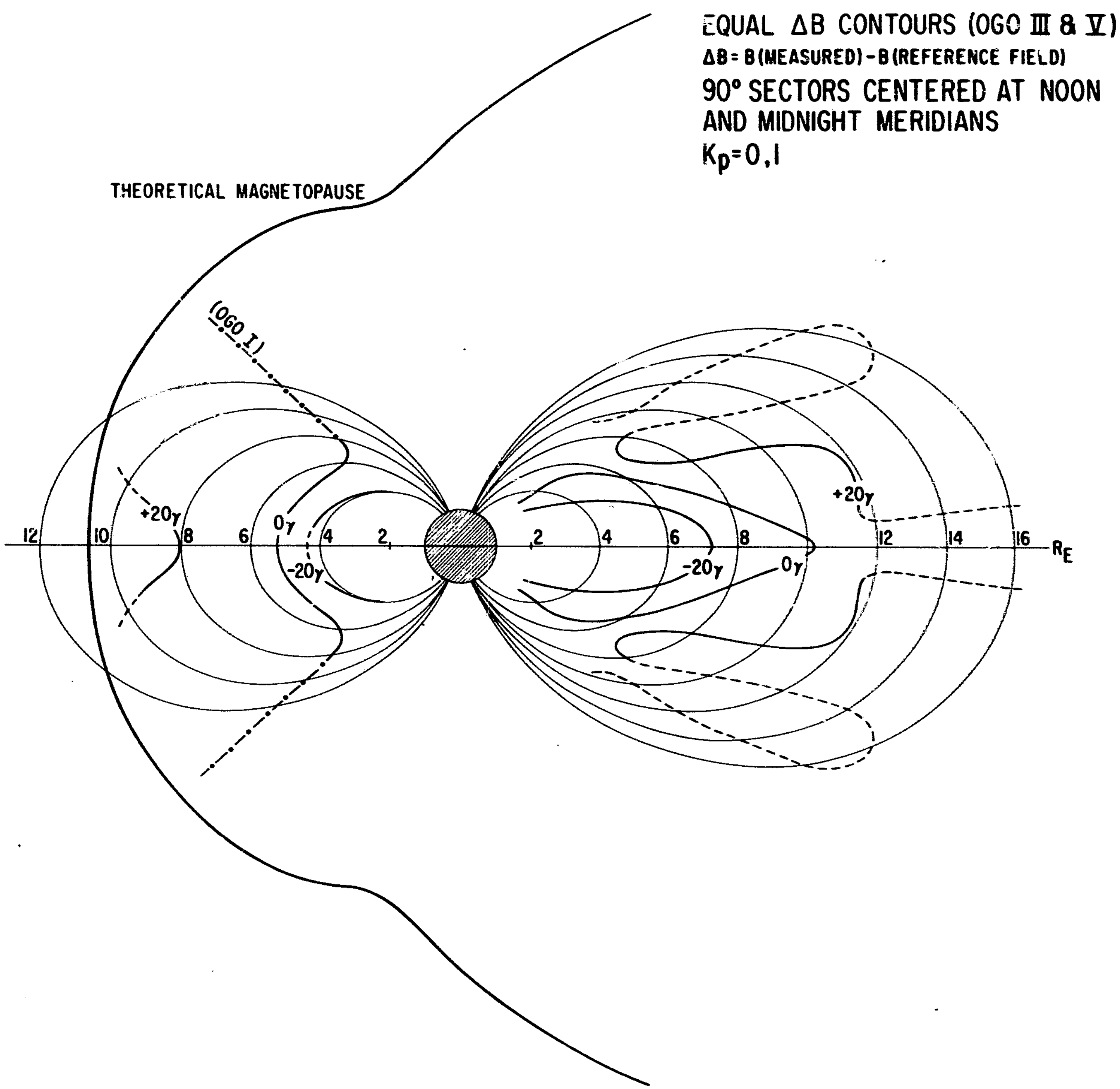
FIGURES

Figure 1. Equi-ΔB contours for 90° sectors centered at the noon and midnight meridian half-planes, in geomagnetic dipole coordinates; Kp = 0 and 1.

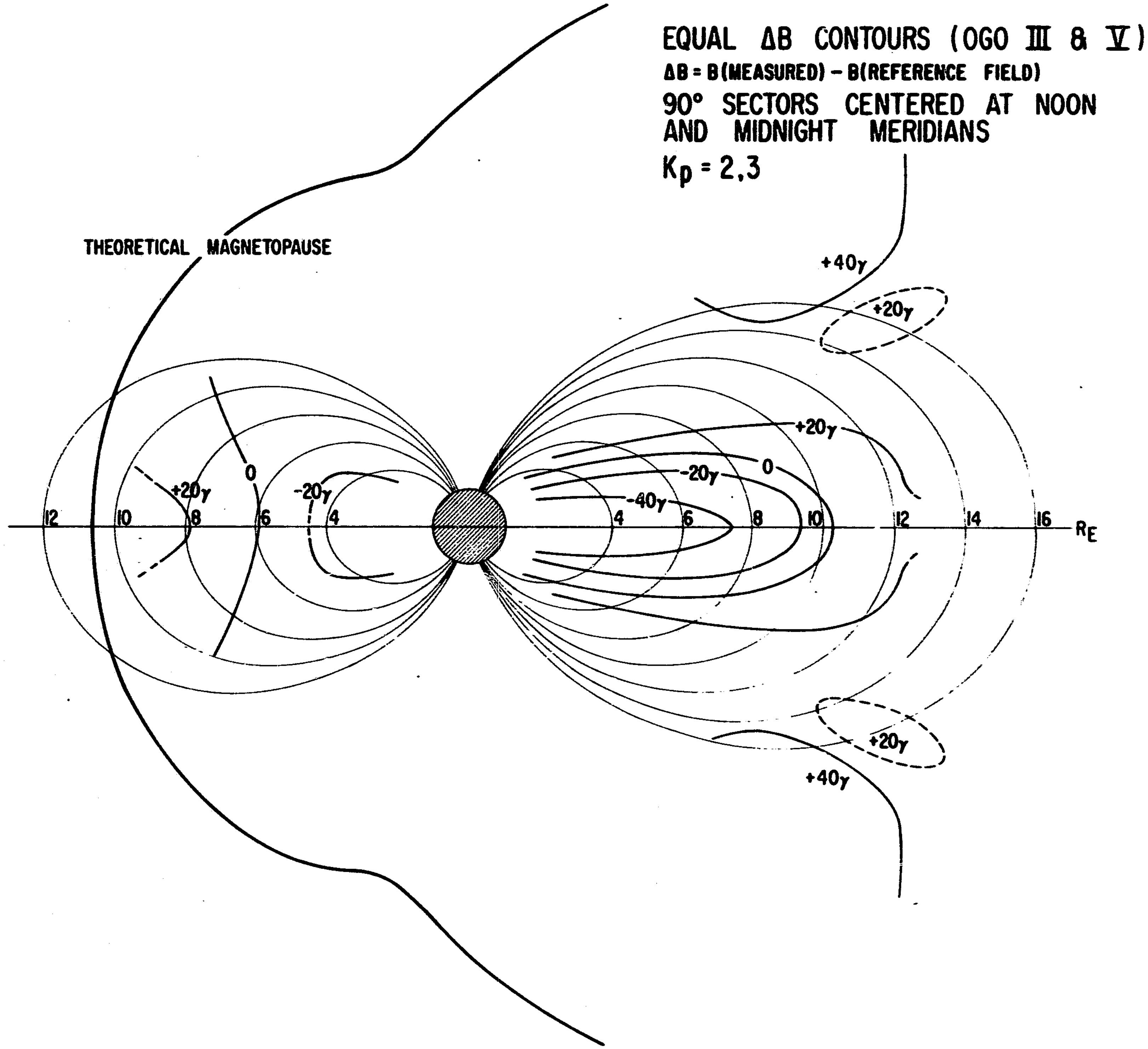
Figure 2. Equi-ΔB contours for 90° sectors centered at the noon and midnight meridian half-planes, in geomagnetic dipole coordinates; Kp = 2 and 3.

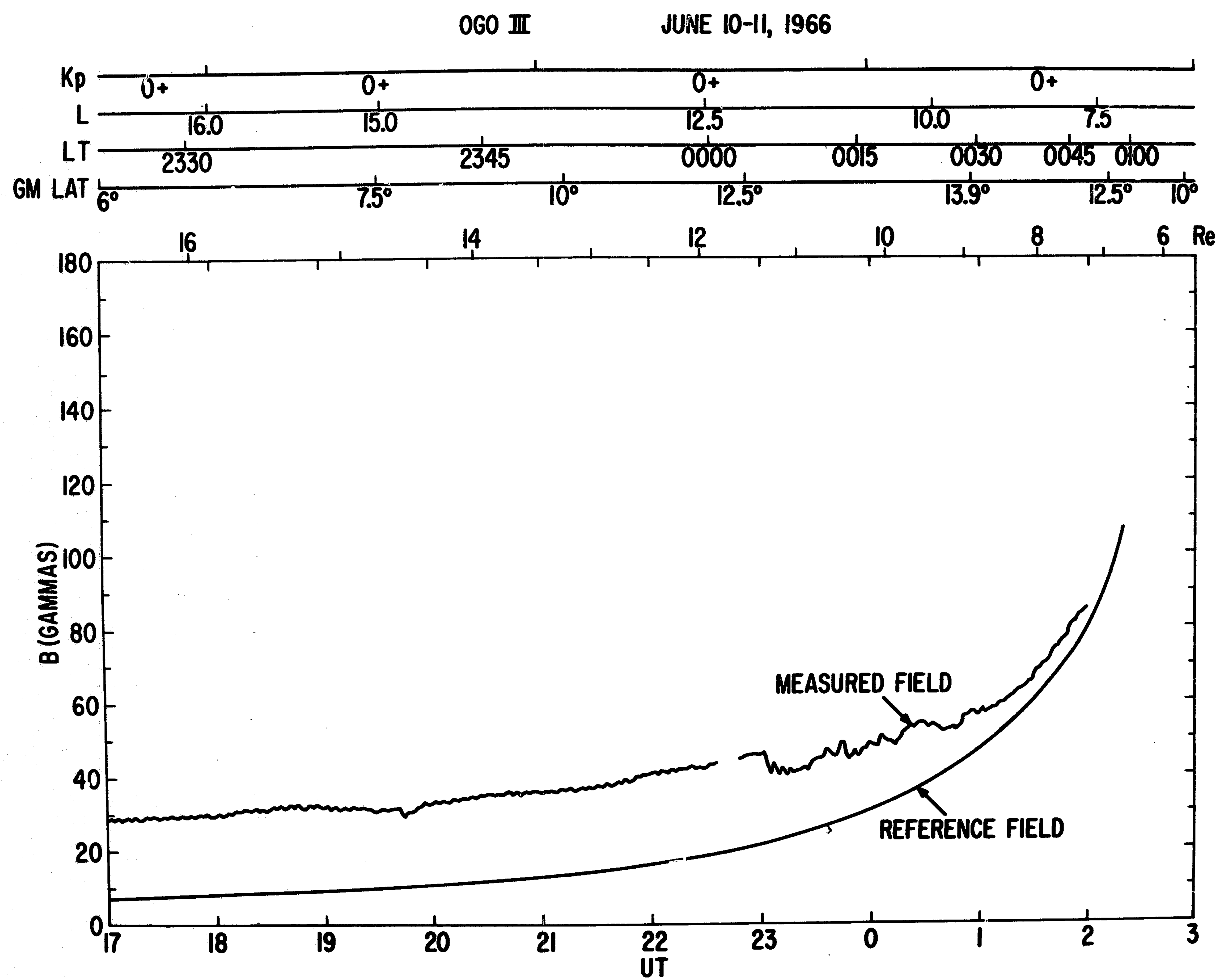
Figure 3. B in the low latitude near tail region. Kp, L, local time, geomagnetic dipole latitude, and geocentric distance in earth-radii are indicated on the top.

Figure 4. B in the equatorial near tail region.

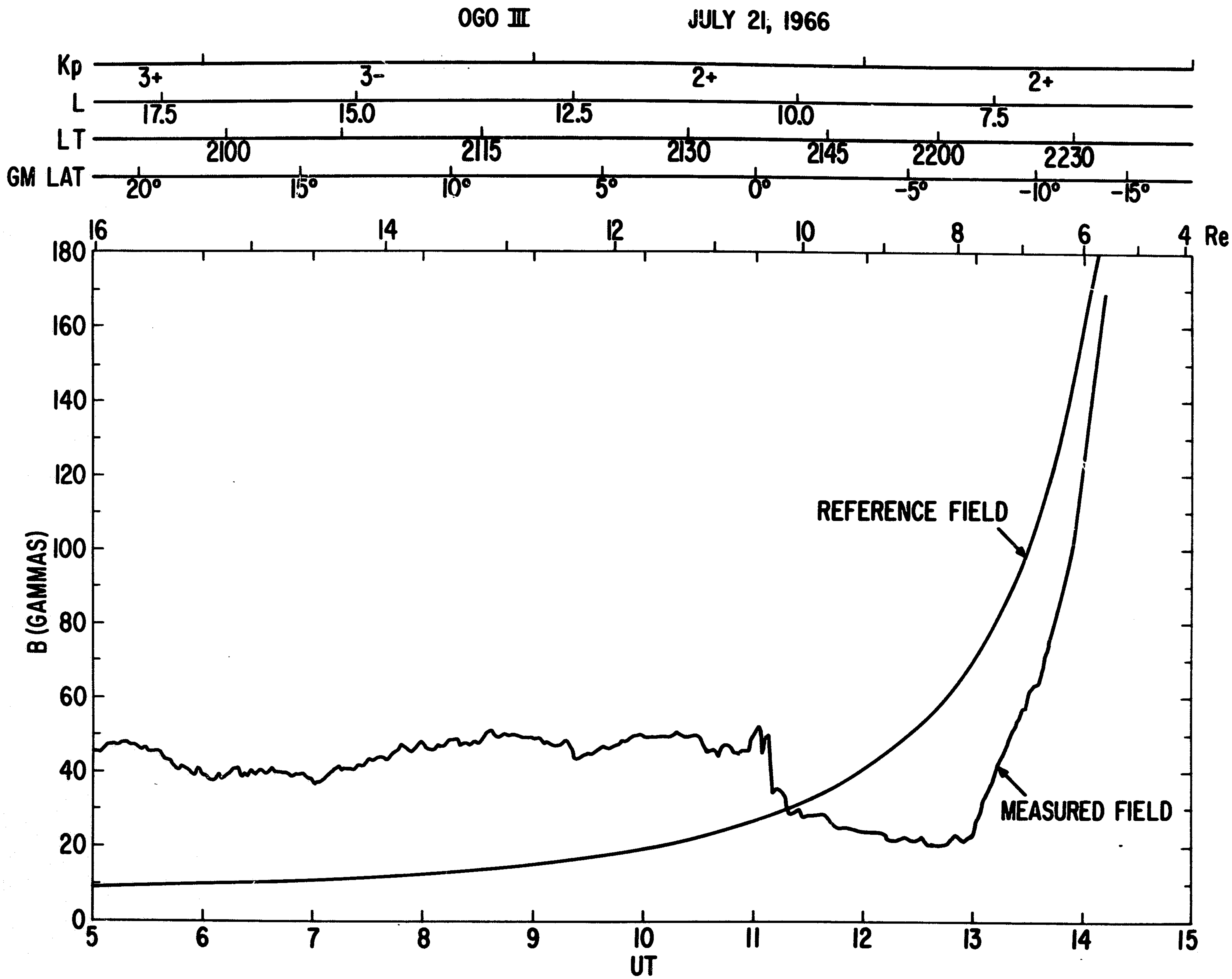


EQUAL ΔB CONTOURS (OGO III & V)
ΔB = B(MEASURED) - B(REFERENCE FIELD)
90° SECTORS CENTERED AT NOON
AND MIDNIGHT MERIDIANS
Kp=0,1
THEORETICAL MAGNETOPAUSE
(OGO I)
+20γ
0γ
-20γ
12
10
8
6
4
2
14
16
RE


EQUAL ΔB CONTOURS (OGO III & V)
ΔB = B(MEASURED) - B(REFERENCE FIELD)
90° SECTORS CENTERED AT NOON AND MIDNIGHT MERIDIANS
Kp = 2,3
THEORETICAL MAGNETOPAUSE
+40γ
+20γ
0
-20γ
-40γ
12
10
8
6
4
14
16
R_E



OGO III
JUNE 10-11, 1966
Kp
L
LT
GM LAT
0+
0+
0+
0+
16.0
15.0
12.5
10.0
7.5
2330
2345
0000
0015
0030
0045
0100
6°
7.5°
10°
12.5°
13.9°
12.5°
10°
16
14
12
10
8
6
Re
180
160
140
120
100
80
60
40
20
0
B (GAMMAS)
MEASURED FIELD
REFERENCE FIELD
17
18
19
20
21
22
23
0
1
2
3
UT


OGO III
JULY 21, 1966
Kp
3+
3-
2+
2+
L
17.5
15.0
12.5
10.0
7.5
LT
2100
2115
2130
2145
2200
2230
GM LAT
20°
15°
10°
5°
0°
-5°
-10°
-15°
16
14
12
10
8
6
4 Re
180
160
140
120
100
80
60
40
20
0
B (GAMMAS)
REFERENCE FIELD
MEASURED FIELD
5
6
7
8
9
10
11
12
13
14
15
UT